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SECONDARY STRESS EFFECTS DURING LOAD INTRODUCTION INTO UNIDIRECTIONAL COMPOSITE TEST COUPONS

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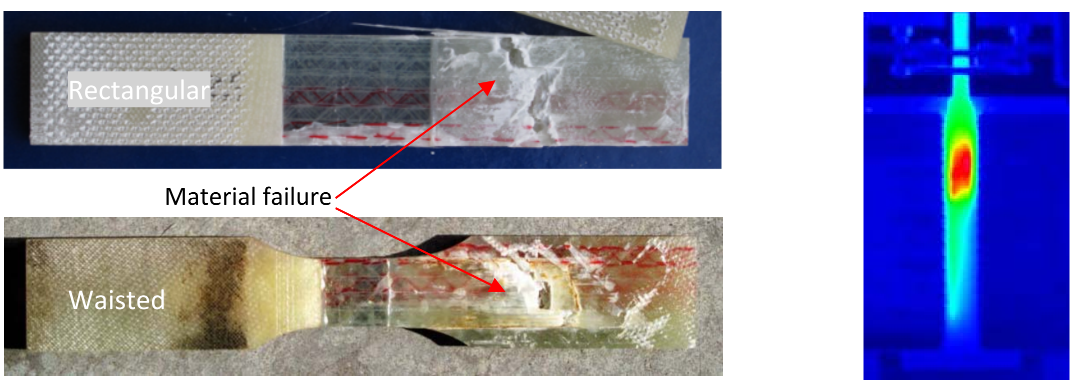
ABSTRACT

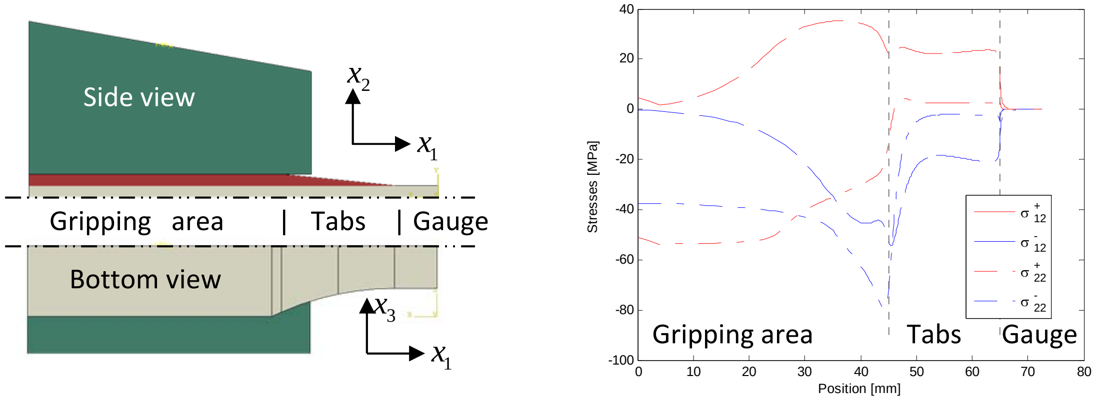
The load introduction in the gripping region during tension and compression test of uni-directional high strength glass and carbon fiber reinforced composites is a big challenge due to the large difference in the tensile and compression strength in the order of 1GPa compared with the shear and transverse tensile strength on 40-60MPa. A difference which is even more pronounced during fatigue loading. Experimental testing typical show failure between the grips both for rectangular and waisted specimens, see figure 1a. Compared with a rectangular specimen, a waisted specimen will in addition exhibit splitting but will in many cases despite this give higher strength measurements. Nevertheless, many of the test samples will still fail between the grips. Therefore, even though the measured values can be considered as a conservative representation of the material strength, the measurements cannot be used comparing the axial strength of different material systems as it is not the pure axial strength of the material which is measured.



a) Failure modes b) Thermography

Figure 1: Rectangular and waisted compression/tension fatigue test samples.

Figure 1a) shows typical failure modes where the tabs are debonded from the test material inside and outside the grips resulting in final material failure outside the gauge section. For the rectangular test samples the debonds occurs in the full width of the specimens while for the waisted test sample, the debonded zone follows the projection of the gauge area into the clamped region, as splitting occur along this projection due to shear stresses distributing stresses from the narrow gauge section to the wide gripping section. For both cases, the final material fails by fiber breakage deep inside the gripping region. In figure 1b) a thermographic image of a test specimen during R=-1 fatigue cycling at 5 Hz is shown. A temperature increase of more than 10-20 degree Celsius and in some cases up to 50 degrees Celsius is found inside the gripping region during fatigue loading. A heat generation which could come from either hysteresis loss due extensive local straining of the material or friction from crack surfaces.



a) Two view of model b) Stress profile along x_1

Figure 2: The finite element model (1/8 due to symmetry) and stress predictions extracted along a path in the test material just below the interface between the test material and the tabs.

Several works, experimental [1] as well as FEM studies [2-3], address the issue of stress concentrations near the tip of the tabs attempting to optimize tab materials and geometries. Contrary, only few studies has focused on secondary stresses inside the grips even though these stresses may introduce tab debonding and premature failure. Figure 2a show a side and bottom (symmetry plane) view of the model where the green, red and gray region corresponds to the grips, tabs and test material, respectively. The grips is in the particular cases loaded by an equally large clamping and axial force on 50kN corresponding to an axial stress $\sigma_{11} \approx 800MPa$ in the gauge section. The grip is fixed against rotation and the interaction between the staggered teeth surface on the grips and the taps is taken into account using a Coulomb friction with a friction coefficient $\mu = 1$. Figure 2b show the predicted stress profile extracted along a path in the gray test material just below the red tab material. The stiff grips results in a rather localized stress state in the much more flexible tab and test material with peaks around the end of the grips both regarding the shear stresses, σ_{12}, and the transverse normal stresses, σ_{22}. For the particular case, it is found that the shear stresses vary between $\sigma_{12} \in [-50;20]\,\mathrm{MPa}$ in this point going from a compressive $()^-$ to a tensile $()^+$ loading which is a critical range regarding fatigue loading specially including additional loading from the other stress components. The stress profile under the grips is found to be very sensitive to the properties of the interface between the taps and the grips but for all realistic cases a rather localized stress profile is found which are in strong contrast to the uniform shear stress condition used in e.g. [3]. An extensive finite element study has been performed compared with experimental measurements observations as the one shown in figure 1.

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